

# POWER METER USING AVR MICROCONTROLLER

KUHENDRAN S/O RAVANDRAN

UNIVERSITI TEKNOLOGI MALAYSIA

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# POWER METER USING AVR MICROCONTROLLER

KUHENDRAN A/L RAVANDRAN

A report submitted in partial fulfilment of the  
requirements for the award of the degree of  
Bachelor of Electrical Engineering (Electronics)

Faculty of Electrical Engineering  
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*Dedicated to my supportive parents for their sacrifice and inspiration,*

*To my siblings for their constant support,*

*To my scintillating lecturers and friends.*

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## **ABSTRACT**

Power consumption has been and still a major concern for energy consumers. Appliance at home and workplace are powered by electricity supplied by the electric utility company. The energy used is measured in kilowatt-hour. After measuring the time that the energy is used cost is then calculated. There should be awareness among energy consumers to monitor and save energy. Saving energy is one way of saving the environment. Therefore, a simple device of energy or power monitoring would help consumers to manage energy effectively. The design of this power meter would include measuring circuit, the microcontroller and a display.

## **ABSTRAK**

Penggunaan kuasa yang telah dan masih menjadi kebimbangan utama bagi pengguna tenaga. Perkakas di rumah dan tempat kerja dibekalkan oleh syarikat utiliti elektrik. Tenaga yang digunakan diukur dalam kilowatt-jam. Selepas pengukuran masa . tenaga yang digunakan, serta kos daripada dikira. Oleh itu, perlu ada kesedaran di kalangan pengguna tenaga untuk memantau dan menjimatkan tenaga. Penjimatan tenaga merupakan salah satu cara menyelamatkan alam sekitar. Oleh itu, peranti mudah untuk memantau tenaga atau kuasa akan membantu pengguna untuk menguruskan tenaga secara berkesan. Reka bentuk meter kuasa ini termasuk litar pengukur, mikropengawal dan paparan LCD.

## TABLE OF CONTENTS

| CHAPTER      | TITLE                        | PAGE  |
|--------------|------------------------------|-------|
|              | <b>DECLARATION</b>           | ii    |
|              | <b>DEDICATION</b>            | iii   |
|              | <b>ACKNOWLEDEGEMENTS</b>     | iv    |
|              | <b>ABSTRACT</b>              | v     |
|              | <b>ABSTRAK</b>               | vi    |
|              | <b>TABLE OF CONTENTS</b>     | vii   |
|              | <b>LIST OF FIGURES</b>       | x     |
|              | <b>LIST OF TABLES</b>        | xiii  |
|              | <b>LIST OF ABBREVIATIONS</b> | xiv   |
| <br><b>1</b> | <br><b>INTRODUCTION</b>      |       |
|              | 1.1 Research Background      | 1     |
|              | 1.2 Problem Statement        | 2     |
|              | 1.3 Objectives of Study      | 2     |
|              | 1.4 Scope of Study           | 3     |
| <br><b>2</b> | <br><b>LITERATURE REVIEW</b> | <br>5 |
|              | 2.1 Existing Products        | 5     |
|              | 2.2 Types of Power           | 6     |
|              | 2.3 Instantaneous Power      | 6     |
|              | 2.4 Active Power             | 7     |
|              | 2.5 Reactive Power           | 7     |
|              | 2.6 Apparent Power           | 8     |

|          |     |                                       |           |
|----------|-----|---------------------------------------|-----------|
|          | 2.7 | Power Factor                          | 9         |
|          | 2.8 | Power Measurement                     | 9         |
|          | 2.9 | Microcontroller                       | 10        |
| <b>3</b> |     | <b>METHODOLOGY</b>                    | <b>13</b> |
|          | 3.1 | Functional Block Diagram              | 13        |
|          | 3.2 | Progress Flow                         | 14        |
|          | 3.3 | Voltage Sensing Circuit               | 17        |
|          | 3.4 | Current Sensing Circuit               | 18        |
|          | 3.5 | Interfacing with LCD                  | 20        |
| <b>4</b> |     | <b>DEVELOPMENT PROCESS</b>            | <b>23</b> |
|          | 4.1 | Simulation Process                    | 23        |
|          | 4.2 | AVR Studio 5                          | 25        |
|          | 4.3 | Software Program Flowchart            | 26        |
|          | 4.4 | PCB Design                            | 32        |
|          | 4.5 | AVR DUDE GUI                          | 35        |
|          | 4.6 | Troubleshooting                       | 36        |
| <b>5</b> |     | <b>RESULTS AND DISCUSSION</b>         | <b>37</b> |
|          | 5.1 | Results                               | 37        |
|          | 5.2 | Discussions                           | 44        |
| <b>6</b> |     | <b>CONCLUSION AND RECOMMENDATIONS</b> | <b>47</b> |
|          | 6.1 | Conclusion                            | 47        |
|          | 6.2 | Recommendations                       | 48        |
|          |     | <b>REFERENCES</b>                     | <b>49</b> |

|                   |    |
|-------------------|----|
| <b>APPENDIXES</b> | 50 |
| Appendix A        | 50 |
| Appendix B        | 54 |
| Appendix C        | 58 |
| Appendix D        | 76 |

## LIST OF FIGURES

| FIGURE NO. | TITLE                                           | PAGE |
|------------|-------------------------------------------------|------|
| 2.1        | Available Power meters in the market            | 6    |
| 2.2        | Power Triangle                                  | 11   |
| 3.1        | Functional Block Diagram for the overall system | 16   |
| 3.2        | Design Procedure                                | 18   |
| 3.3        | Design Process                                  | 19   |
| 3.4        | The Voltage Transformer and connection diagram  | 21   |
| 3.5        | Shunt Resistor                                  | 23   |
| 3.6        | Overall Circuit                                 | 24   |
| 3.7        | Liquid Crystal Display                          | 26   |
| 3.8        | HD44780-based LCD kit                           | 27   |
| 4.1        | Proteus Simulation                              | 29   |
| 4.2        | AVR Studio 5 Interface                          | 30   |
| 4.3        | Program Initializations                         | 32   |

|     |                                                                       |    |
|-----|-----------------------------------------------------------------------|----|
| 4.4 | Cycle Service                                                         | 34 |
| 4.5 | Save Measurement                                                      | 35 |
| 4.6 | Timer and ADC initialization                                          | 37 |
| 4.7 | PCB Schematic                                                         | 38 |
| 4.8 | PCB Layout                                                            | 39 |
| 4.9 | AVR Dude GUI                                                          | 42 |
| 5.7 | Output voltages versus input voltage for actual and displayed voltage | 51 |
| 5.8 | Output current versus input current for actual and displayed current  | 52 |
| 5.9 | Output power versus input power for actual and displayed power        | 53 |

## LIST OF TABLES

| TABLE NO. | TITLE                                                                                                                                              | PAGE |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 2.3       | Comparison Between Microcontrollers                                                                                                                | 13   |
| 5.1       | Test Results for the Voltage Sensing Circuit<br>without Load                                                                                       | 45   |
| 5.2       | Test Results for the Current Sensing Circuit<br>without Load                                                                                       | 46   |
| 5.3       | Simulation test results for the Power Meter with<br>Load<br><br>Resistor(R), Inductor (L) and Capacitor(C)                                         | 47   |
| 5.4       | Calculated results for the Power Meter with Load<br><br>Resistor(R), Inductor(L) and Capacitor(C) and<br>Average Error (%) compared with Table 5.3 | 48   |
| 5.5       | Hardware test results of the Power Meter with Load<br><br>Resistor(R), Inductor (L) and Capacitor(C)                                               | 49   |

|     |                                                                                                                                               |    |
|-----|-----------------------------------------------------------------------------------------------------------------------------------------------|----|
| 5.6 | Calculated results for the Power Meter with Load<br>Resistor (R), Inductor (L) , Capacitor (C) and<br>Average Error (%) compared to Table 5.5 | 50 |
|-----|-----------------------------------------------------------------------------------------------------------------------------------------------|----|

## LIST OF ABBREVIATIONS

|                  |   |                             |
|------------------|---|-----------------------------|
| AC               | - | Alternate Current           |
| DC               | - | Direct Current              |
| ADC              | - | Analog-to-Digital converter |
| V <sub>in</sub>  | - | Input voltage               |
| V <sub>o</sub>   | - | Output voltage              |
| RMS              | - | Root Mean Square            |
| DC               | - | Direct Current              |
| V <sub>p-p</sub> | - | Peak-to-peak voltage        |

## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 Research Background**

Energy is an important physical element in our daily lives. Every moment we live we consume and release energy. Nowadays world, energy consumption is very high. As for this matter efforts have to be taken in saving energy consumption. Hereby, question arises on what does 'Energy Saving' means. Energy saving or vice-versa is an effort to plan and reduce energy in domestic usage. Furthermore, we should be aware on the importance of energy saving. Our main concern in saving energy is that to reduce pollution caused due to generating energy, for example burning coal to generate electricity and car fumes causes air pollution. Besides that we can save water by saving energy. Power stations use 2 liters of water for every unit of electricity (kWh) generated.

Furthermore we can save more money if we use less energy. In Malaysia most of the energy consumed is by natural gaseous and electricity. So the best possible way to reduce energy is by monitoring energy consumption in daily usage.

## **1.2 Problem Statement**

Today, awareness of saving energy has been quite high due to the efforts taken by the government and the authorities in reaching the public. These phenomena had created a new path of business opportunity for tools and devices related to monitoring and saving energy.

The existing products in the market in monitoring the electricity consumption and its efficiency commonly known as Energy Meter or Power Meter are complex and high at cost. Due to this problem it is not popular and well received in the market.

Furthermore, it is necessary for a tool or device to be user friendly. There are Power Meters in the market that provides many functions, but its operation is hard and difficult to be understood by the user.

Besides that, a tool or device should be compact and weigh less. These features are an important trend to gain the market attention as it is more compatible and require less space.

## **1.3 Objectives of Study**

The main objectives of this project are to design a Power Meter using AVR-ATMEL microcontroller. To develop a hardware (PCB ) for the designed Power Meter and finally the designed power meter should be able to measure voltage ( $V_{rms}$ ) , current ( $I_{rms}$ ) and active power (P) and power factor in single phase distribution environment.

## **1.4 Scope of Study**

The scope of the project is that the designed Power meter operates with single phase voltage source used is 230v 50 Hz freq. Furthermore, this Power Meter can only measure one Channel at a time

## **1.5 Outline of Thesis**

This report consists of 6 main chapters which are Introduction, Theory and Literature Review, Research Methodology, Development Process, Result and Discussion, and Conclusion and Recommendation. Chapter 1 which is Introduction consists of research background, problem statement, objectives of study, and summary of works and complete work plan. Meanwhile, Chapter 2 which is Theory and Literature Review consists of literature review of the project. Next, chapter 3 discussed about the Research Methodology of the project. Chapter 4 is about the Development Process which includes problems faced and its solutions. Chapter 5 is explained about Result and Discussion of the project. Finally, chapter 6 discussed about Conclusion and Recommendation for the project.

## **CHAPTER 2**

### **THEORY AND LITERATURE REVIEW**

#### **2.1 Existing Products**

The most common Power Meter designs which are available in the market is the Brands Electronic Digital Power Meter as shown in Figure 2.1 (a) .This meter is comparatively large in size and not user friendly. Furthermore, the price range of this product is USD\$ 149- USD\$349. This is expensive for domestic purpose use. The next model as shown in Figure 2.1 (b) is the Kill-a-watt which costs USD \$60.



(a)



(b)

**Figure 2.1** Available Power Meters in the market

## 2.2 Types of Power

In the electrical power technology, the concept of active, reactive, and apparent power creates a major impact. In electrical energy transmission it is often easier to understand by working with power, rather than dealing with voltages and current.

The terms active, reactive, and apparent power apply to steady-state alternating current circuits in which the voltages and currents are sinusoidal. They cannot be used to describe transient-state behavior, nor can we apply them to do DC circuits.

Our study begins with an analysis of the instantaneous power in an AC circuit. We then go on to define the meaning of active and reactive power. This is followed by a definition of apparent power, power factor, and the power triangle.

## 2.3 Instantaneous Power

The instantaneous power supplied to a device is simply the product of instantaneous voltage across its terminals times the instantaneous current that flows through it. Instantaneous power is always expressed in watts, irrespective of the type of circuit used. The instantaneous power may be positive or negative. A positive value means that power flows into the device. On the other hand, a negative value indicates that power is flowing out of device.

## 2.4 Active Power

Also sometimes known as real power, active power,  $P$  is the rate of energy conversion or dissipation taken as an average of one or more complete cycles and it is independent of time. Our main power distributor, Tenaga Nasional Berhad (TNB) monitors this power in determining monthly electricity bills. This power may range from a few microwatts, in applications such as satellite communications, to, megawatts; in application such as supply the electrical needs of large cities. The implementation of the active power measurement is relatively easy and is done accurately in most energy meters in field.

## 2.5 Reactive Power

Reactive power,  $Q$ , involves real power that oscillates back and forth between two devices over a transmission line. The active power mentioned before is unidirectional. The reactive power is also given by

$$Q = V \times I \quad (1)$$

However, to distinguish this power from active power, another unit is used- the var. When  $V$  and  $I$  are out of phase, a reactive power reading is obtained. Thus

$$Q = V \times I \times \sin \theta \quad (2)$$

Where

$\theta$  = the phase angle between  $V$  and  $I$

If  $V$  and  $I$  are exactly in phase, the reading is zero.

## 2.6 Apparent Power

Loads that absorb both active power  $P$  and reactive power  $Q$  may be considered to be made up of a resistance and an inductive reactance. It also could be said as the rate at which energy is absorbed by an element and the maximum real power that can be delivered to a load. Apparent power is expressed neither in watts nor in vars, but in voltamperes.

The apparent power is an important quantity in engineering applications because its maximum value must be limited to all physical devices. For this reason, the maximum apparent or peak power at the input exceed the limit power, the output signal will be distorted. So, the exceeding input rating may even damage amplifier permanently.

$$S = V_{RMS} \times I_{RMS} \quad (3)$$

Where  $V_{rms}$  and  $I_{rms}$  are the effective voltage and current delivered to the load, the equation is as shown above.

## 2.7 Power Factor

The power factor of an alternating current device or circuit is the ratio of the active power  $P$  to the apparent power  $S$ . It is given by the equation

$$\text{Power factor} = P/S \quad (4)$$

Where

$P$  = active power delivered or absorbed by the circuit or device [W]

$S$  = apparent power of the circuit or device [VA]

Power factor is expressed as a simple number, or as a percentage. Because the active power  $P$  can never exceed the apparent power  $S$ , it follows that the power factor can never be greater than unity (or 100 percent). The  $S = V_{RMS} \times I_{RMS}$  relationship brings can form a triangle which is called the power triangle as follows:

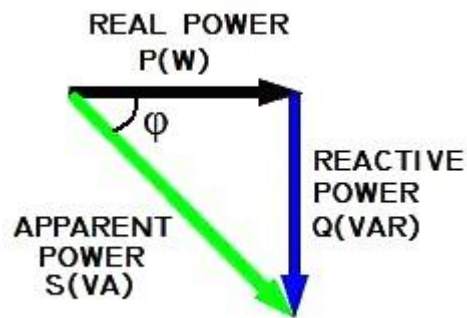


Figure 2.2 Power Triangle

## 2.8 Power Measurement

Basically, a Power Meter is designed to measure energy of power. In simple terms, as we understand, electrical power is the product of voltage and current. If we make repeated measurements of both instantaneous voltage and current, or  $V_i$  and  $I_i$ , we can keep a running total of their products over time. By dividing each parameter reading by the number of samples, we can measure the average power. For alternating current, such as that from the mains, average power also must account for the power factor as discussed previously, which is the phase relationship between voltage and current. It is known that it is difficult for a microcontroller to make direct measurements when the supply voltage is coming straight off the mains: say, 240V. This makes it necessary to

indirectly measure line voltage and current. The best way to reduce the voltage to a level and dynamic range is that is compatible with digital circuitry. This applies for current as well.

## 2.9 Microcontroller

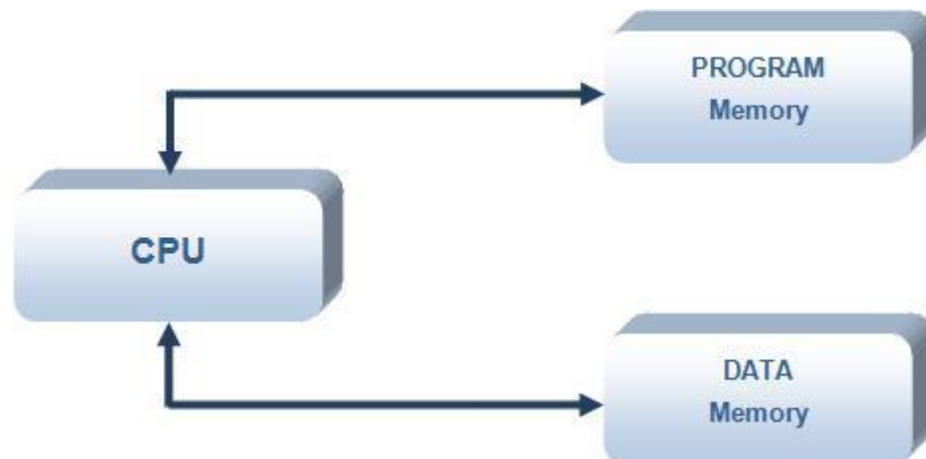
A microcontroller is an essential element in designing the Power meter. Microcontroller is designed for embedded applications. These applications are automatically controlled products and device. As there are many type of microcontrollers available in the market such as the AVR-ATMEL microcontroller, the PIC microcontroller, the Intel 8051 microcontroller and many more.

|              | 8051        | PIC      | AVR     |
|--------------|-------------|----------|---------|
| SPEED        | Slow        | Moderate | Fast    |
| MEMORY       | Small       | Large    | Large   |
| ARCHITECTURE | CISC        | RISC     | RISC    |
| ADC          | Not Present | Inbuilt  | Inbuilt |
| TIMERS       | Inbuilt     | Inbuilt  | Inbuilt |
| PWM          | Not Present | Inbuilt  | Inbuilt |

**Table 2.3** Comparison between microcontrollers

From the above table it is known that the AVR-ATMEL microcontroller is the best option although it is very similar to the PIC microcontroller and far better than the 8051 microcontroller but it is the fastest microcontroller among the microcontrollers compared above. Furthermore, the **AVR microcontroller** executes the instructions in single execution cycle. Besides that, this microcontroller has the ability to operate in different power saving modes. Finally, the AVR microcontroller is very much cost effective as it saves more power.

The advanced RISC architecture and 32 x 8- bit general purpose working registers are the core elements in the AVR microcontroller. The AVR can fetch inputs from two general purpose working registers and put them to ALU for carrying out the requested operation, and transfer back the result to an arbitrary register within one clock cycle. The ALU can perform arithmetic as well as logical operations over the inputs from the register or between the register and a constant. Single register operations like taking a complement can also be executed in ALU. We can see that AVR does not have any register like accumulator as in 8051 family of microcontrollers; the operations can be performed between any of the registers and can be stored in either of them. AVR follows Harvard Architecture format in which the processor is equipped with separate memories and buses for Program and the Data information. Here while an instruction is being executed, the next instruction is pre-fetched from the program memory.



Since AVR can perform single cycle execution, it means that AVR can execute 1 million instructions per second if cycle frequency is 1MHz. The higher is the operating frequency of the controller, the higher will be its processing speed. We need to optimize the power consumption with processing speed and hence need to select the operating frequency accordingly.

## CHAPTER 3

### METHODOLOGY

#### 3.1 Functional Block Diagram

Below is a functional diagram of the overall system that is used to design the power meter.

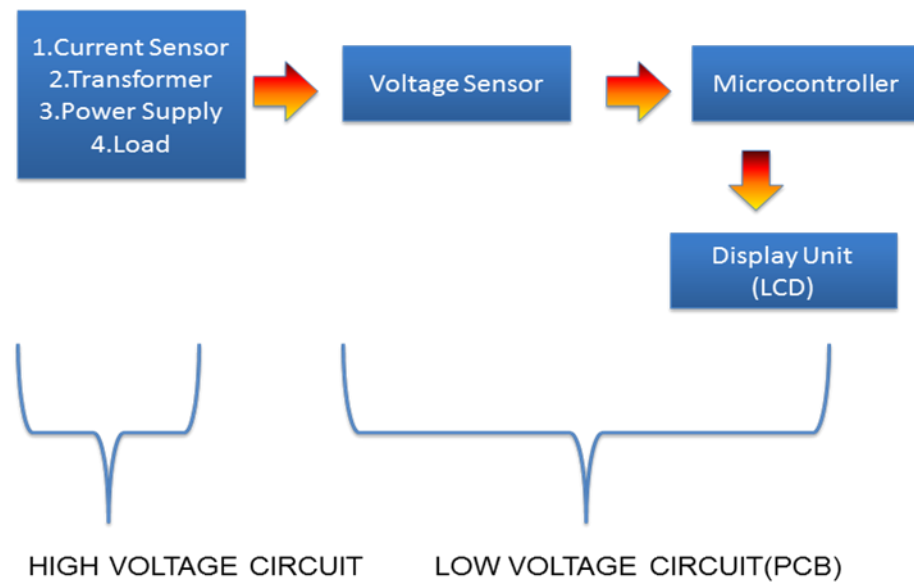


**Figure 3.1** Functional Block Diagram of the Overall System

### 3.2 Progress Flow

Below is the flow chart of the methodology which is used for this project. The first stage is background study. During this stage, much research is done to understand power and energy measurement. Also, studies on previous design are also done. The microcontroller and its basic function is understood in this stage. Several researches were done on voltage and current sensors, as well as analog to digital (A/D) converters. Next, I obtained the core information of the project learning how to use the software below:-

- a) Proteus      c) AVR studio5
- b) Eagles      d) AVR dude GUI compiler

The next stage in the second part of thesis (PSMII) is the design of the circuit itself, programming the microcontroller, selecting hardware, constructing the power meter, and result analysis.

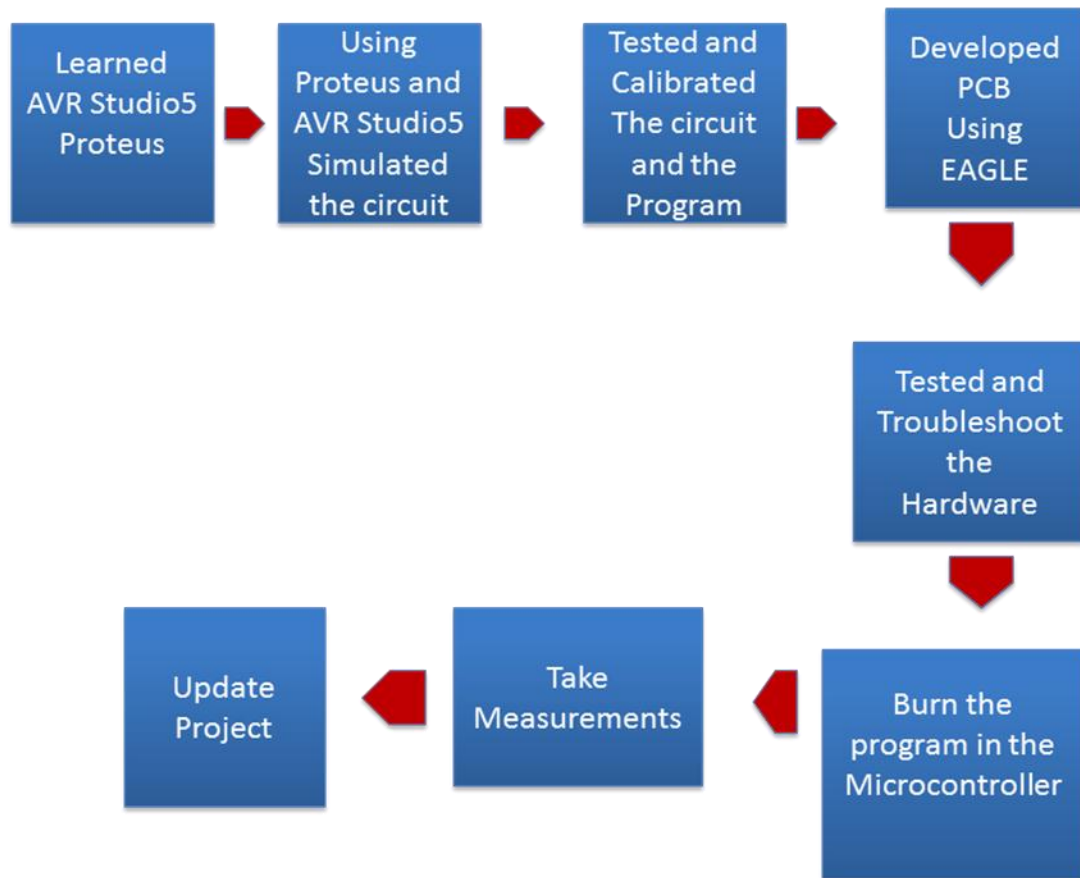


**Figure 3.2** Design Procedure

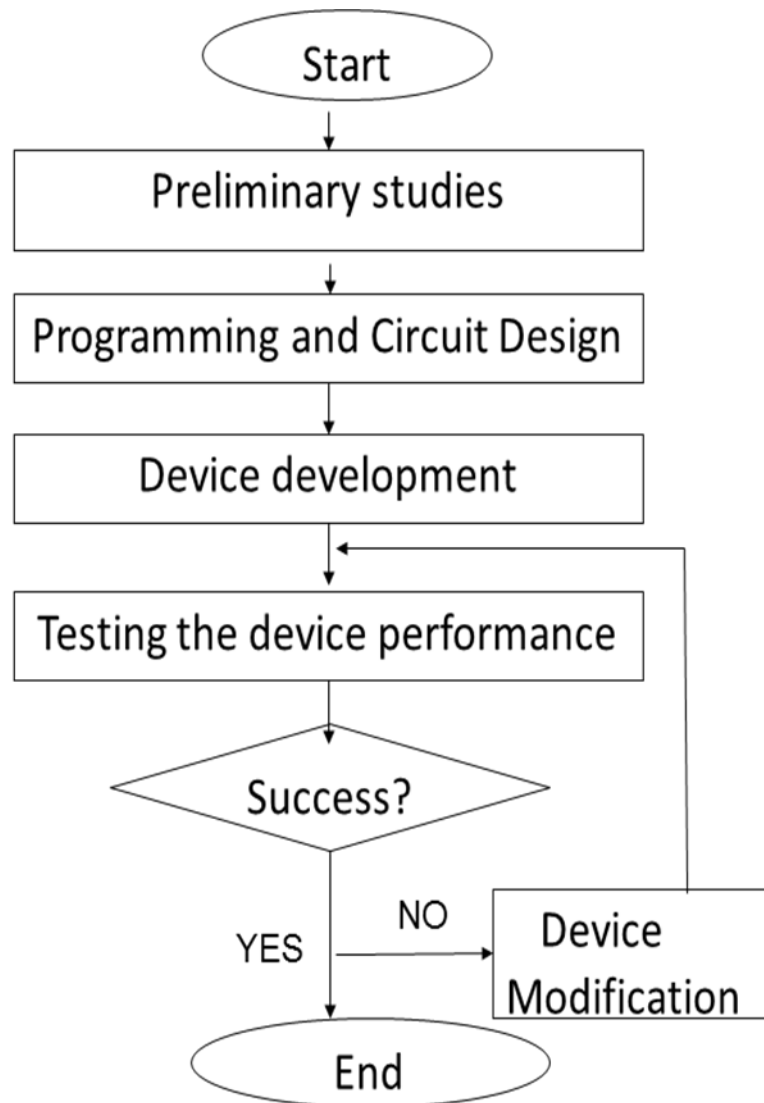


**Figure 3.3** Design Process

### 3.3 Voltage Sensing Circuit

The circuit used in hardware design must be non-intrusive, which means the circuit itself should not consume power because this factor can reduce accuracy of the power meter. Therefore, the voltage-sensing circuit has to be both accurate and non-intrusive. Next, the voltage sensing circuit cannot handle input as high as 240Vrms, which means the input voltage had to be stepped down to decrease the input read by the voltage sensing circuit. Furthermore, in using microcontroller it had to ensure that the microcontroller does not receive not more than 5V. These are the core factors which had to be ensured before designing the voltage-sensing circuit.

A Encapsulated PCB mounted voltage transformer as shown in the figure below is used to step down the primary input voltage of 240Vrms to 12Vrms secondary output voltage. This was chosen because it is small in size, which is only 22.0 x 22.7mm

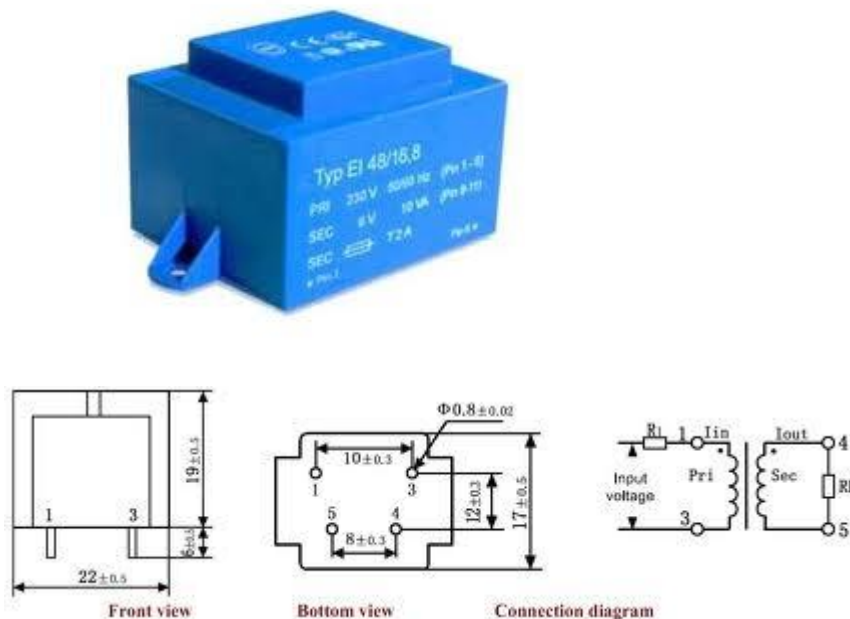


**Figure 3.4** The Voltage Transformer and connection diagram

The voltage from input is stepped down from 240Vrms to 12Vrms, which is then divided using a voltage divider R1 100kohm and R2 10kohm.

### 3.4 Current Sensing Circuit

For the current sensing circuit a shunt resistor of 0.05 ohm is used. Using shunt resistor as the current sensing circuit saves cost and produces an accurate measurement. Shunt resistors can provide either a high-side or low side measurement of the current through the load. High-side current measurement has more complex circuitry than low side method .In this design , the low side current shunt measurement was used because low voltage op-amps can be used to sense voltage across the shunt resistor. This is because the measurement is referenced to ground.

The International Standard IEC1036 (1996-09) Alternating Current Energy Meters of Active Energy (Classes 1 and 2) calls for a maximum power dissipation of 2 Watts. For this design , a 0.005ohm shunt resistor was selected, with a maximum current of 3A , the maximum power dissipated in the shunt is

$$3^2 \times 0.05 = 0.45W$$

which is well below standards. A 0.05ohm shunt resistor shown in Figure 3.5 with a power rating of 1W, and small dimensions of 5.08 mm height and 11.43 mm length proves to be suitable size and economical for this design.



**Figure 3.5** The Shunt Resistor

With that, at  $I_{max}$  (3A), the voltage drop across the shunt would be,

$$3 \times 0.05 = 0.15V$$

this is rather small as the maximum range of current should be 0-5V for maximum range across the ADC of the microcontroller.

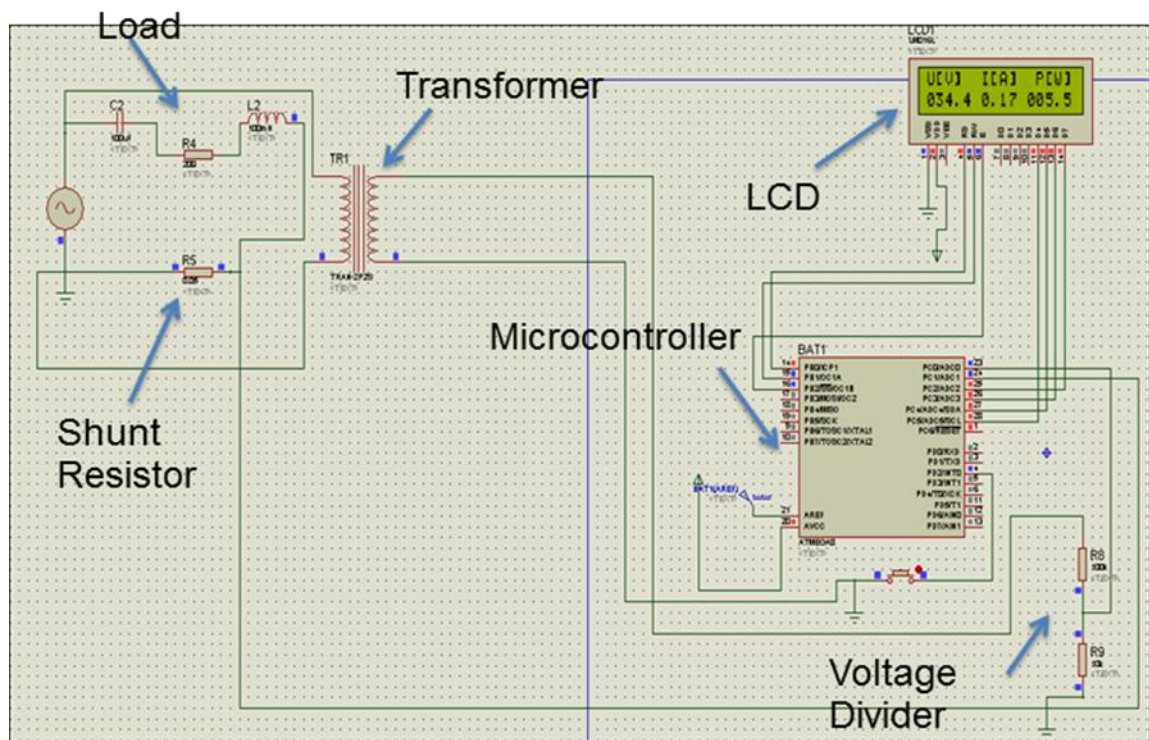


**Figure 3.6** The Overall Circuit

### 3.5 Interfacing to the Liquid Crystal Display

The usage of seven segment-displays is generally simple but due to its bulky size and limited set of characters proves not suitable for this project. The seven- segment becomes inadequate when more than few letters or digit displayed. Liquid Crystal Display (LCDs) come in handy when the application requires the display of many characters. An LCD has the following advantages:

- High contrast
- Low power consumption
- Small footprint
- Ability to display both letters and graphics

The basic construction of an LCD is showed in Figure 3. .The LCD allows light to pass through when activated. A segment is activated when low-frequency bipolar signal in a range of 30Hz to 1000Hz is applied to it. The polarity of the voltage must alternate or else the LCD will not be able to change quickly.

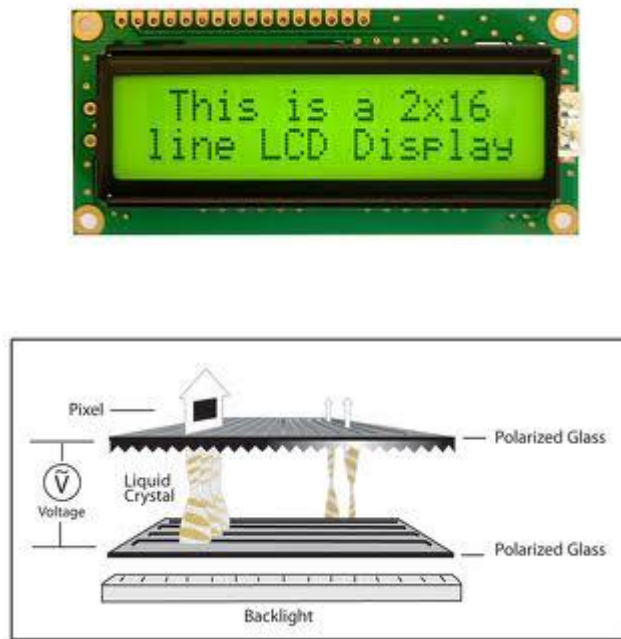


**Figure 3.7** Liquid Crystal Display

In the recent years, price of LCDs has become more affordable. LCDs are often sold in modules that consists both LCD and its controller. The Hitachi 44780 is one of the most popular LCD display controllers in use today.

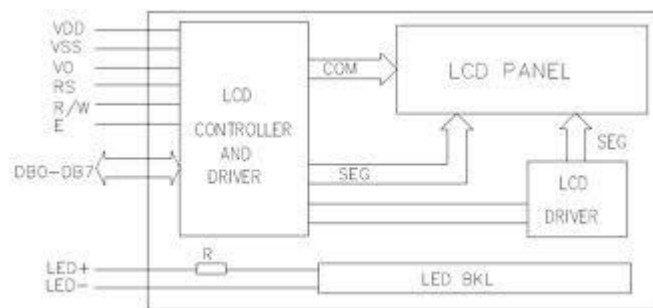


**Figure 3.8** The HD44780-based LCD kit

The DB0-DB7 pins can be used to exchange data with the microcontroller. In this project, a 4-bit interface is used, so only pins DB4-DB7 are used. The E pin is an enable signal to the kit. The R/W signal determines the direction of the data transfer. The

RS signal selects the register to be accessed . When the RS signal is high, the data register is selected. Otherwise, the instruction register is selected. The VEE is used to control brightness of the display and is connected to a potentiometer. The VEE input should be set to maximum value (-VCC) for an extended period of time before burning the LCD.

## **CHAPTER 4**

### **DEVELOPMENT PROCESS**

#### **4.1 Simulation Process**

In order to test the program, before building the hardware, a simulation tool comes very handy as it helps to verify the program before the real hardware is built. This part of the process saves cost in case of hardware changes during the design process. Furthermore, the simulation tool also enables us to simulate and watch the intended system performance by connecting the hardware simulation prototype to the oscilloscope. Therefore, Proteus a simulation application which has a rich library is used to design the power meter. Besides that, this application enables user to load .hex file to the microcontroller to run the program.

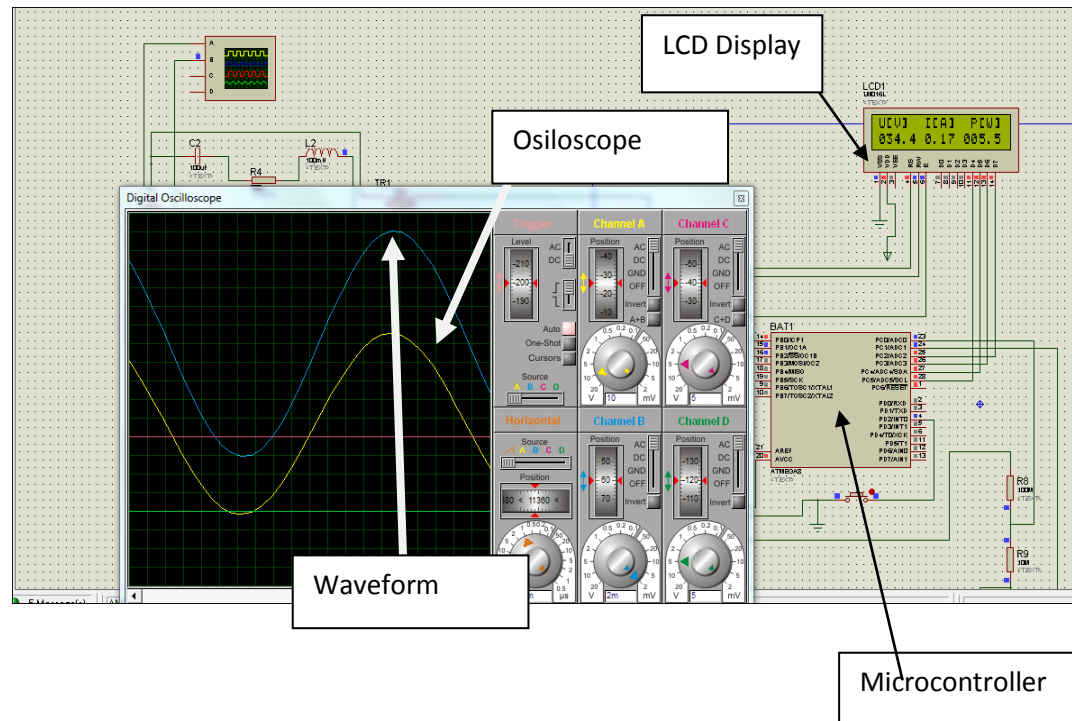


**Figure 4.1** Proteus Simulation

Figure 4.1 above shows the features of the simulation tool and its operation, this shows how this tool helps to improve the design performance and useful in analyzing results.

## 4.2 AVR Studio 5

AVR studio 5 is a platform used to program and compile the ATMEGA 8 , microcontroller which is used in this design. This software have a similar Graphical User Interface (GUI) as the Visual Basic(VB) software. Therefore it is easy to program C/C++ language of programming which is used in this design. The C/C++ is the better version of programming compared to assembly language because it is easy for programmers to reference and user to understand the program as well.

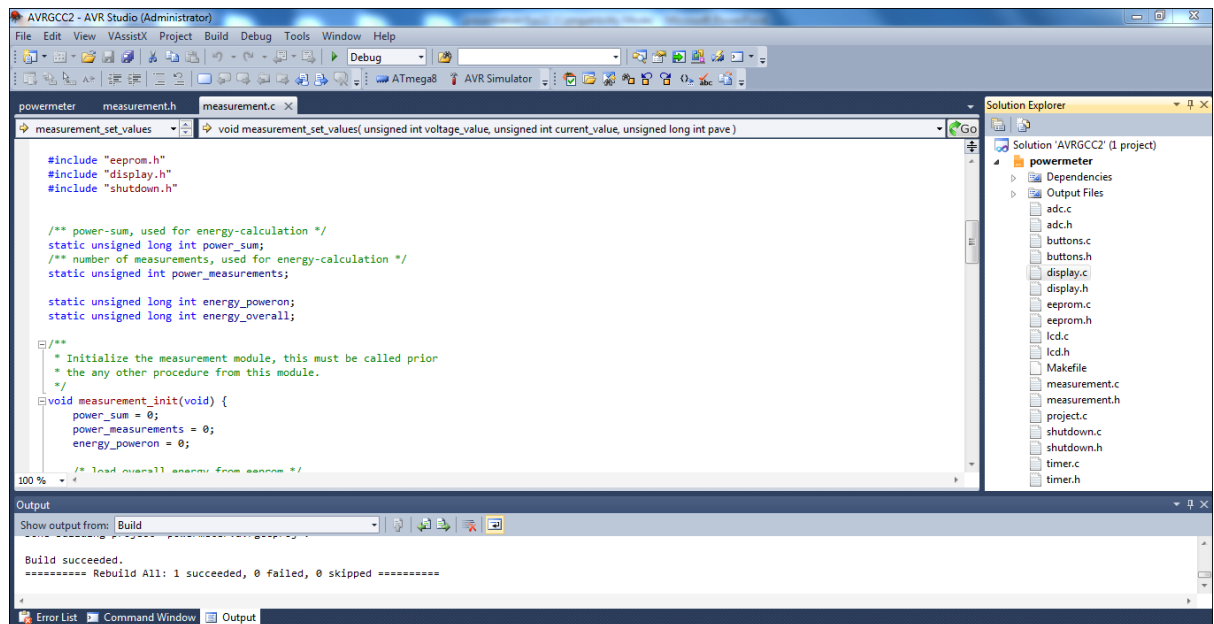
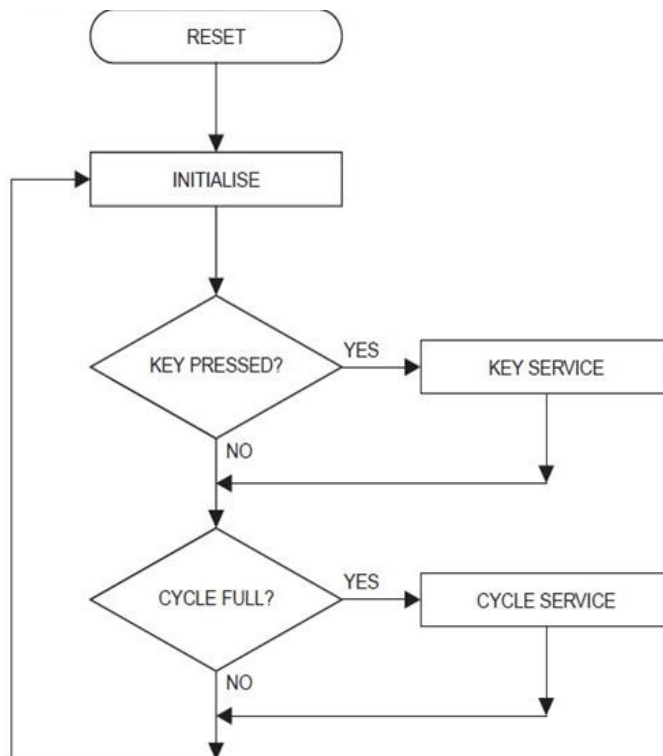


Figure 4.2 AVR Studio 5 Interface

Figure 4.2 above shows the program in the AVR Studio 5. By using this software, we can save time in using other software or application to produce .hex file which is later burned into the microcontroller.

### 4.3 Software Program Flow Chart

To program the AVR-ATMEL microcontroller, the GCC compiler is used. Below is the flow chart of the entire program. The GCC C compiler was designed to exclusively for the AVR-ATMEL microcontroller. The compiler has a large library built-in-functions, preprocessor commands and ready-to-run example programs to start any project.



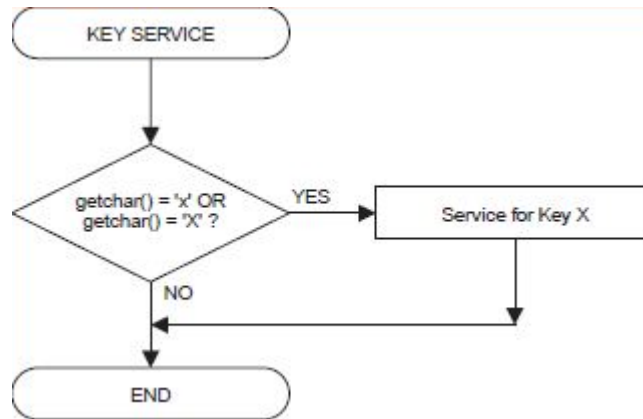
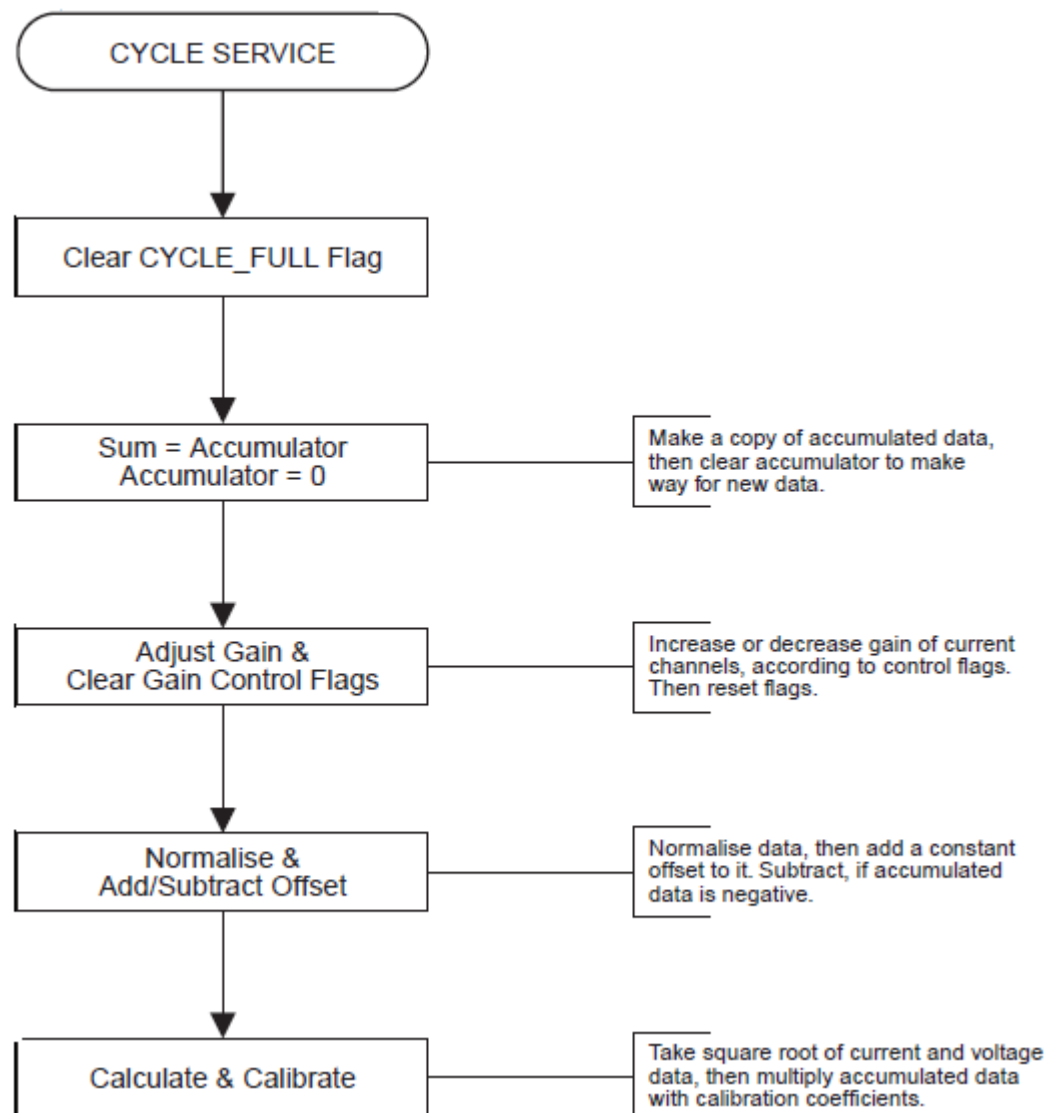
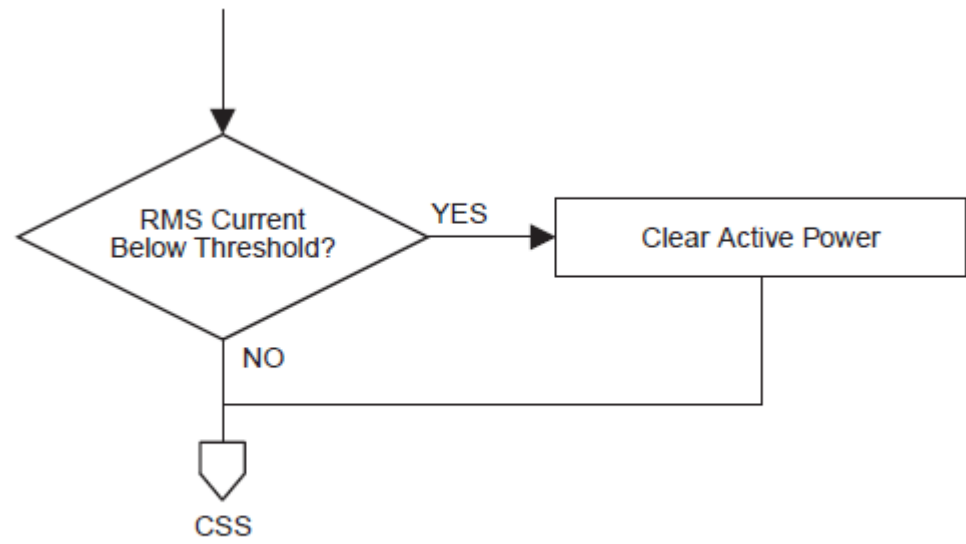


**Figure 4.3** Program Initializations





(Continued on next page)

**Figure 4.4** Cycle Service

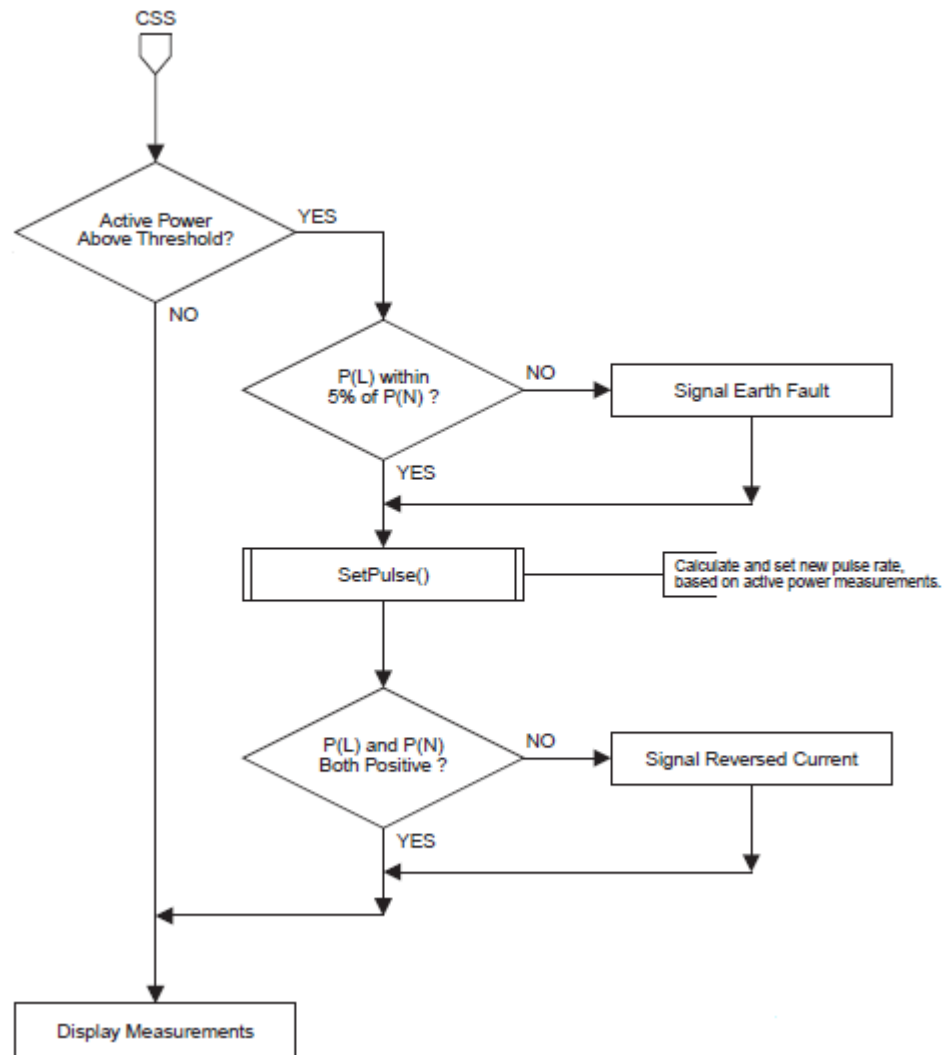
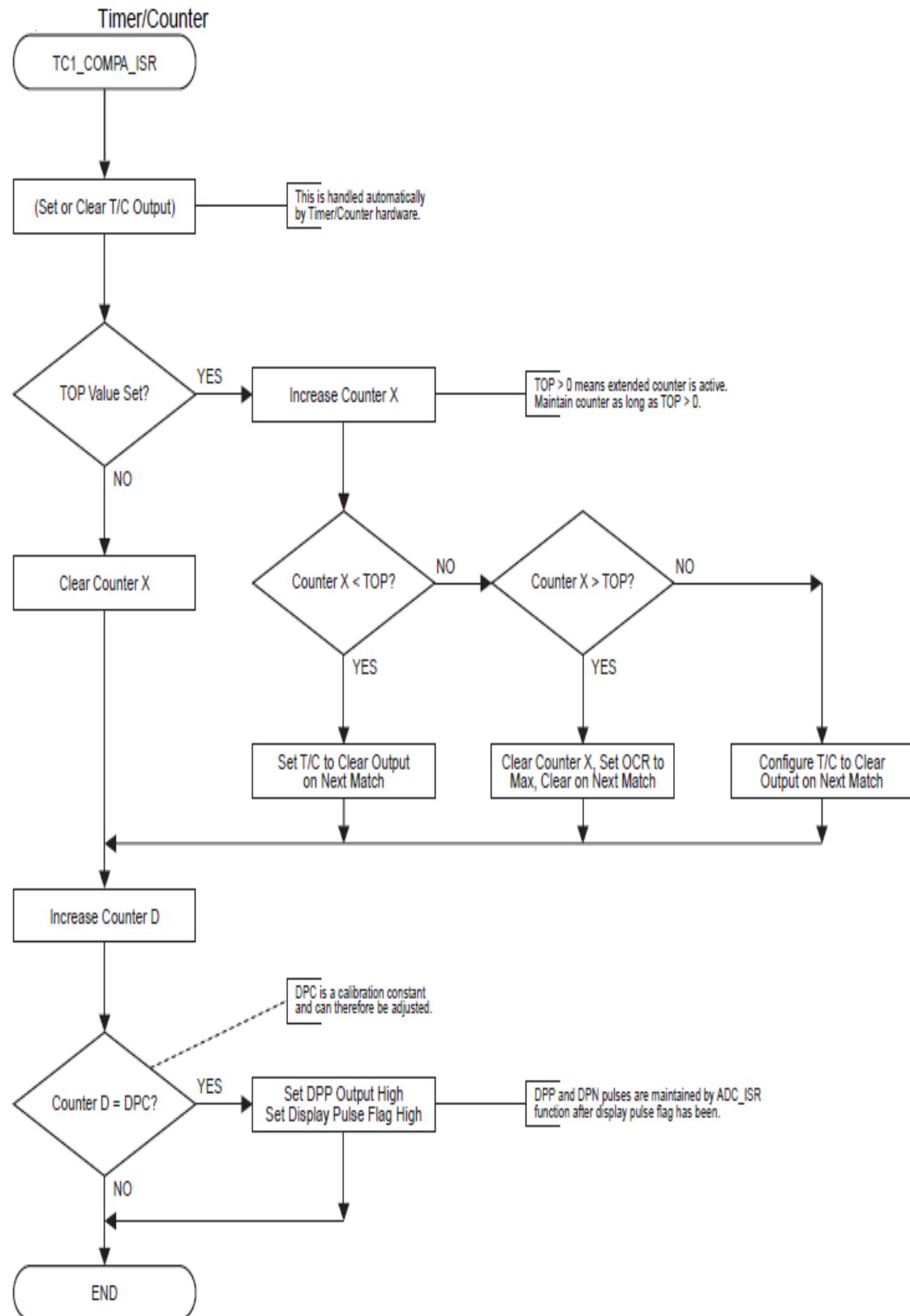


**Figure 4.5** Save Measurement

## Timer/Counter ISRs



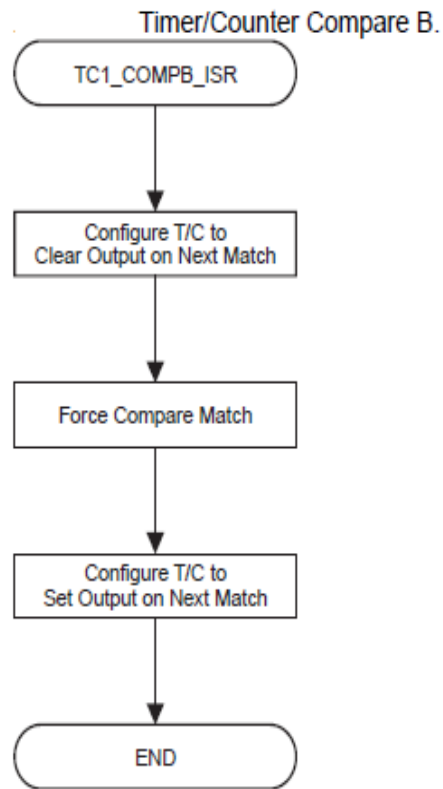


**Figure 4.6** Timer and ADC initialization

Following that, the AVR is burned with AVR ISP programmer with AVR Dude GUI. It is a third party tool which supports the development program. It is the software that programs the \*.hex file into the IC through the COM port of computer.

#### **4.4 Printed Circuit Board (PCB) Design**

PCB is used a platform to place all components in the board neatly and with less soldering compare to normal bread board or donut board. Furthermore, it assists well in troubleshooting the hardware. Eagles is the software used to design the PCB. This software, in particular is user friendly and have a very rich library which can be updated from time to time. There are a few steps had to followed in designing the PCB. Firstly, the schematic is drawn using the software. Next it is converted to layout. From the layout, the component is once again placed in various way until a optimized designed with low space is acquired. Finally, routing is done by connecting each component which was set initially the connection in the schematic. This process can be done manually or by simply setting “autorouting”. This feature helps the user to route all the components automatically.

Figure 4.7 and 4.8 Shows the PCB schematic and the PCB layout.

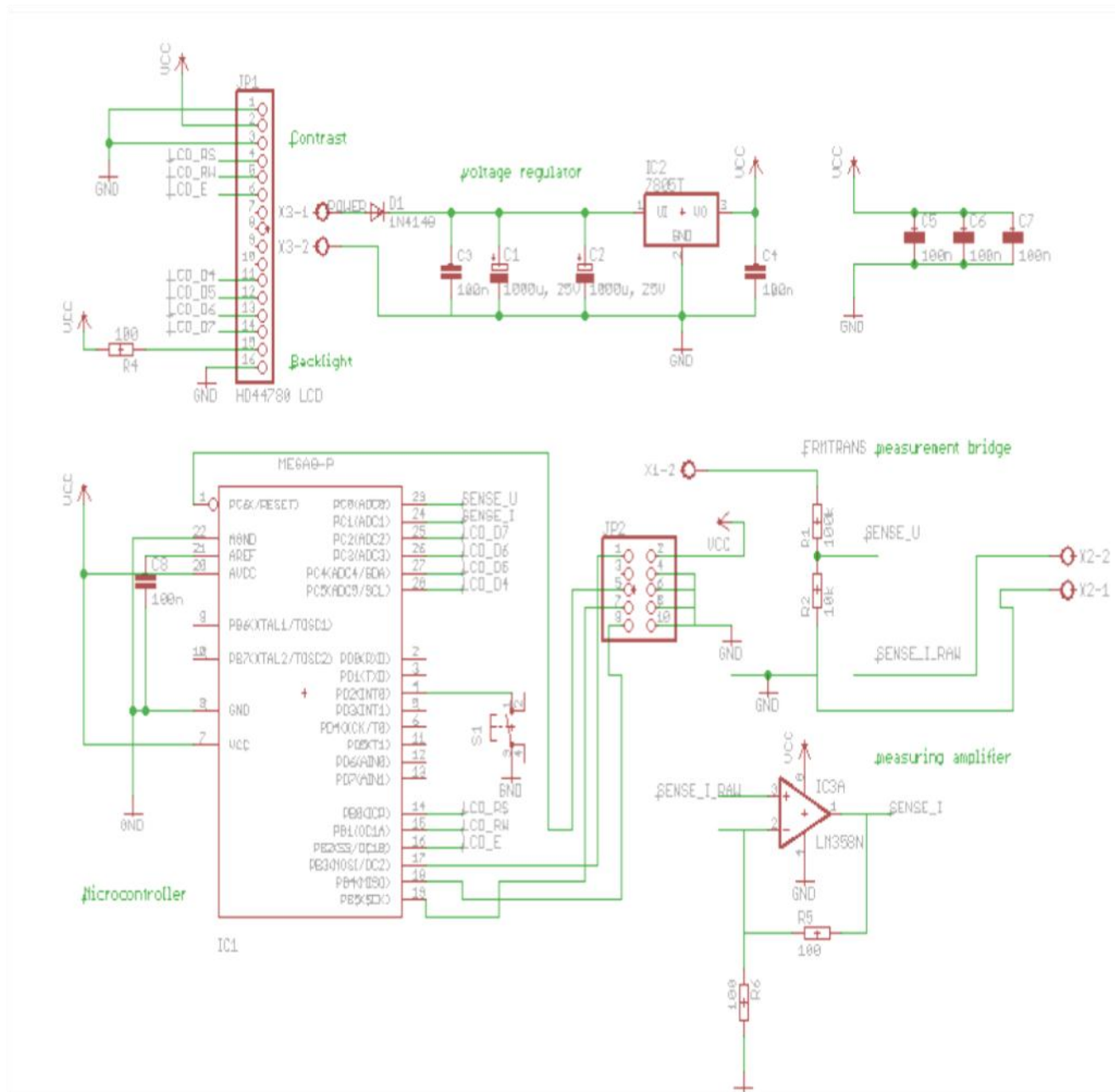


**Figure 4.7** PCB Schematic

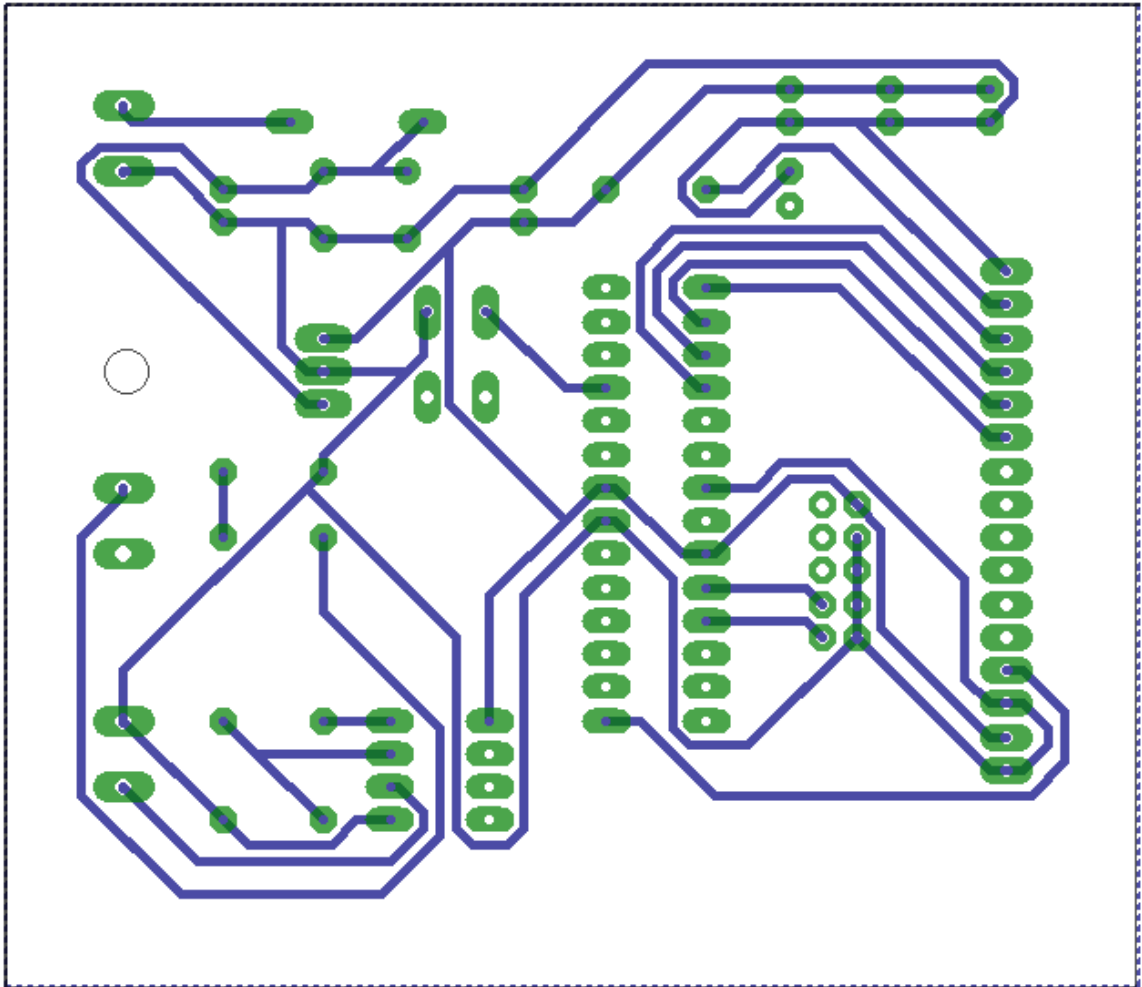


**Figure 4.8** PCB Layout

## 4.5 AVR Dude GUI

AVR Dude GUI is the simple GUI application as the name suggests which is used to burn the program into the microcontroller. It is very easy to use as users need not have to set any fuse bit values as required by many other AVR based burner.

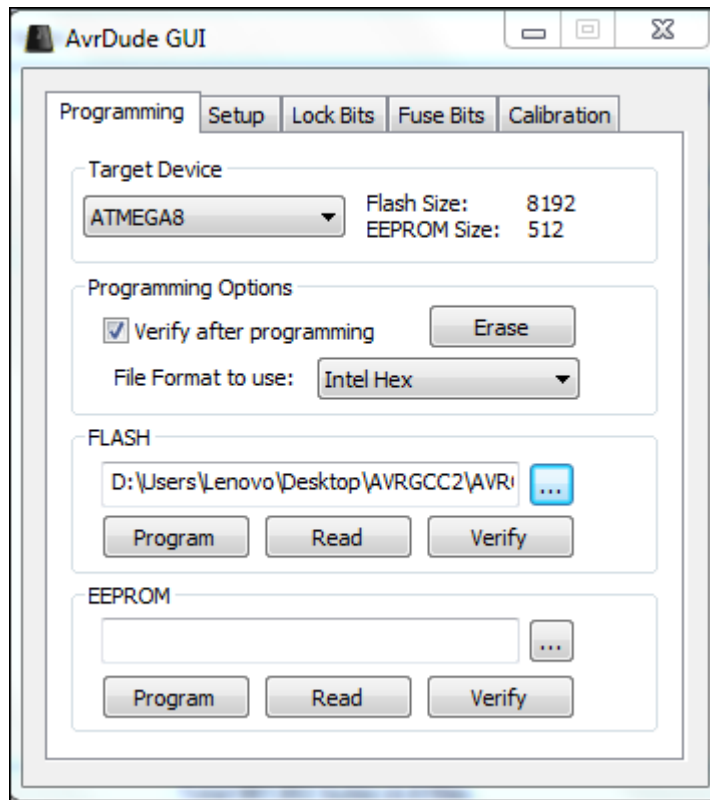


**Figure 4.9** AVR Dude GUI

## 4.6 Troubleshooting

There were few problems occurred in completing this project, firstly in the simulation part the value obtained in the output which gives an error value more than 20%. Therefore, calibration has been done in order to overcome this problem. The calibration was done by obtaining a series of data comparing the actual value and the output value, a graph was plotted and a coefficient is found by obtaining the perfect straight line since all equation involved in this calculation are linear. Next, the coefficient value is added in the equation and another series of data is obtained. This process is repeated until a satisfactory value is obtained.

Next, is troubleshooting the PCB board. After soldiering all components it is found that some of the components which should be connected is not connected in the PCB board. This was due to a very thin line in the PCB itself was not connected properly. Therefore, jumper wires were used to connect all the missing connection in the PCB board. Finally, a connection which supposedly connected to ground was accidentally connected to VCC, this was due to improper soldiering, the problem was detected by checking each connection in the circuit using a digital multimeter.

## **CHAPTER 5**

### **RESULTS AND DISCUSSIONS**

#### **5.1 Results**

Several tests were carried out to verify the readings and also obtain findings for the voltage sensing and current sensing circuits, while still in simulation process before the real hardware was designed. Tables below shows the obtained test results for voltage sensing and current sensing circuit.

**Table 5.1** Test Results for the Voltage Sensing Circuit without Load

| <b>ACTUAL<br/>VOLTAGE<br/>Input Voltage (V)</b> | <b>DISPLAYED<br/>VOLTAGE<br/>Output Voltage (V)</b> | <b>Error<br/>%</b> |
|-------------------------------------------------|-----------------------------------------------------|--------------------|
| 0                                               | 000.0                                               | 0.0                |
| 40                                              | 038.8                                               | 3.1                |
| 80                                              | 077.7                                               | 2.9                |
| 120                                             | 120.0                                               | 0.0                |
| 160                                             | 159.9                                               | 0.1                |
| 200                                             | 202.2                                               | 1.1                |
| 240                                             | 240.0                                               | 0.0                |

**Table 5.2** Test Results for the Current Sensing Circuit without Load

V<sub>in</sub>=120 V<sub>rms</sub>

| <b>ACTUAL<br/>CURRENT<br/>Input Current (V)</b> | <b>DISPLAYED<br/>CURRENT<br/>Output Current (V)</b> | <b>Error<br/>%</b> |
|-------------------------------------------------|-----------------------------------------------------|--------------------|
| 0                                               | 0.00                                                | 0.0                |
| 0.5                                             | 0.48                                                | 4.0                |
| 1.0                                             | 0.98                                                | 2.0                |
| 1.5                                             | 1.48                                                | 1.3                |
| 2.0                                             | 2.01                                                | 0.5                |
| 2.5                                             | 2.50                                                | 0.0                |
| 3.0                                             | 3.00                                                | 0.0                |

Table 5.3 shows the simulation results and Table 4.4 shows the calculated results for the power meter with Resistor(R), Inductor(L), and Capacitor (C) connected in series as load.

**Table 5.3** Simulation test results for the Power Meter with Load  
Resistor(R), Inductor (L) and Capacitor(C)

Vin=120 Vrms

| <b>POWER<br/>METER<br/>DISPLAY</b> | <b>R=100 <math>\Omega</math><br/>L=100mH<br/>C=100uF</b> | <b>R=100 <math>\Omega</math><br/>L=100mH<br/>C=10uF</b> | <b>R=100 <math>\Omega</math><br/>L=300mH<br/>C=100uF</b> | <b>R=120 <math>\Omega</math><br/>L=100mH<br/>C=100uf</b> | <b>R=200 <math>\Omega</math><br/>L=250mH<br/>C=50uF</b> |
|------------------------------------|----------------------------------------------------------|---------------------------------------------------------|----------------------------------------------------------|----------------------------------------------------------|---------------------------------------------------------|
| V(V)                               | 120.0                                                    | 120.0                                                   | 120.0                                                    | 120.0                                                    | 120.0                                                   |
| I(A)                               | 1.20                                                     | 0.49                                                    | 0.88                                                     | 0.98                                                     | 0.60                                                    |
| Power (P)                          | 138.8                                                    | 29.9                                                    | 83.3                                                     | 115.5                                                    | 65.5                                                    |
| Power Factor                       | 0.9                                                      | 0.4                                                     | 0.7                                                      | 0.9                                                      | 0.9                                                     |

**Table 5.4** Calculated results for the Power Meter with Load Resistor(R), Inductor(L) and Capacitor(C) and Average Error (%) compared with Table 5.3

Vin=120 Vrms

| POWER<br>METER<br>DISPLAY | R=100 $\Omega$<br>L=100mH<br>C=100uF | R=100 $\Omega$<br>L=100mH<br>C=10uF | R=100 $\Omega$<br>L=300mH<br>C=100uF | R=120 $\Omega$<br>L=100mH<br>C=100uf | R=200 $\Omega$<br>L=250mH<br>C=50uF | Average<br>Error<br>% |
|---------------------------|--------------------------------------|-------------------------------------|--------------------------------------|--------------------------------------|-------------------------------------|-----------------------|
| V(V)                      | 120.0                                | 120.0                               | 120.0                                | 120.0                                | 120.0                               | 0.0                   |
| I(A)                      | 1.19                                 | 0.48                                | 0.90                                 | 0.99                                 | 0.58                                | 1.9                   |
| P(W)                      | 142.2                                | 23.3                                | 82.3                                 | 118.8                                | 69.0                                | 6.7                   |
| Power<br>Factor           | 0.99                                 | 0.4                                 | 0.76                                 | 0.99                                 | 0.9                                 | 5.2                   |

Table 5.5 shows the hardware test results and Table 4.6 shows the calculated results .

**Table 5.5** Hardware test results of the Power Meter with Load Resistor(R), Inductor (L) and Capacitor(C)

$V_{in}=34.4 \text{ V}_{rms}$

| POWER<br>METER<br>DISPLAY | R=100 $\Omega$<br>L=100mH<br>C=100uF | R=200 $\Omega$<br>L=100mH<br>C=100uF | R=100 $\Omega$<br>L100mH<br>C=200uF | R=100 $\Omega$<br>L=200mH<br>C=100uf |
|---------------------------|--------------------------------------|--------------------------------------|-------------------------------------|--------------------------------------|
| V(V)                      | 34.0                                 | 34.0                                 | 34.0                                | 34.0                                 |
| I(A)                      | 0.35                                 | 0.17                                 | 0.39                                | 0.30                                 |
| Power (P)                 | 010.0                                | 005.5                                | 009.9                               | 008.8                                |
| Power Factor              | 0.9                                  | 0.9                                  | 0.9                                 | 0.8                                  |

**Table 5.6** Calculated results for the Power Meter with Load Resistor (R), Inductor (L) Capacitor (C) and Average Error (%) compared to Table 5.5

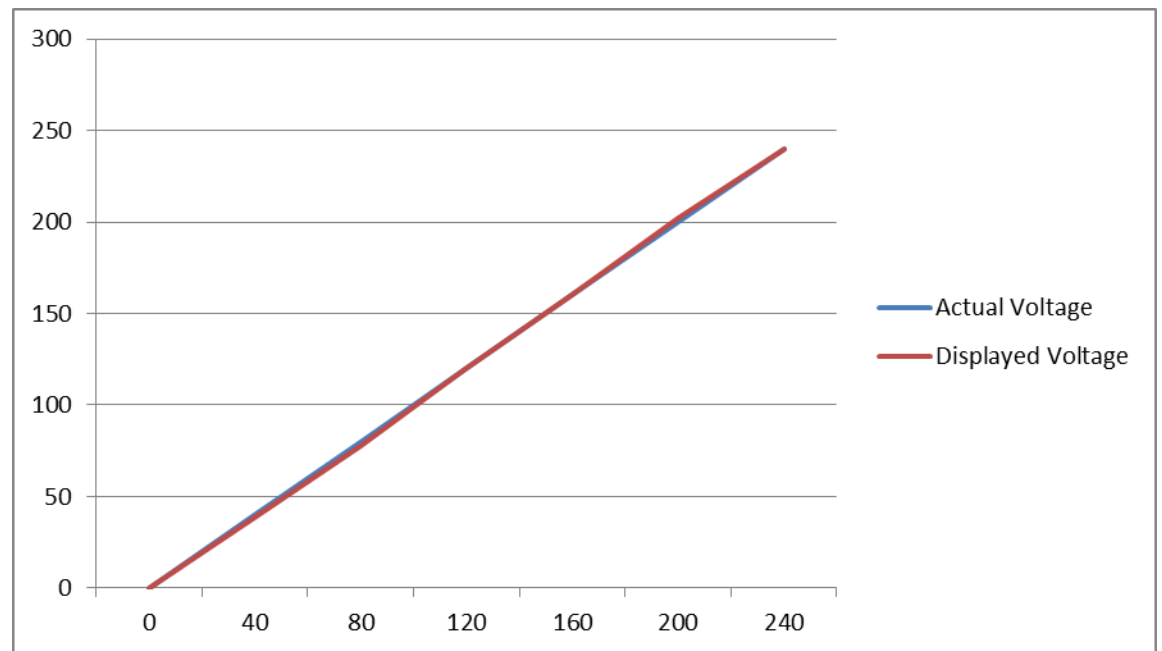
Vin=34.4 Vrms

| POWER<br>METER<br>DISPLAY | R=100 $\Omega$<br>L=100mH<br>C=100uF | R=200 $\Omega$<br>L=100mH<br>C=100uF | R=100 $\Omega$<br>L=100mH<br>C=200uF | R=100 $\Omega$<br>L=200mH<br>C=100uf | Average<br>Error<br>% |
|---------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|-----------------------|
| V(V)                      | 34.4                                 | 34.4                                 | 34.4                                 | 34.4                                 | 1.2                   |
| I(A)                      | 0.34                                 | 0.17                                 | 0.33                                 | 0.31                                 | 3.4                   |
| Power (P)                 | 11.69                                | 5.89                                 | 11.17                                | 9.55                                 | 10.0                  |
| Power Factor              | 0.9                                  | 0.9                                  | 0.9                                  | 0.8                                  | 9.1                   |

## 5.2 Discussion

The voltage sensing hardware tests were conducted by varying a 0 – 240 Vrms input and shows the output of the LCD display in Proteus simulation. The results was shown in Table 5.1 as well as a graph in Figure 5.7 which shows that there is a linear increase in the output voltage versus the input voltage. Therefore, the voltage sensing circuit is accurate and it gives a 1.17% error.

**Output Voltage (V)**



**Input Voltage (V)**

**Figure 5.7** Output voltages versus input voltage for actual and displayed voltage.

The current sensing hardware tests were conducted by setting 120 Vrms input voltage as constant and by varying the load value and obtaining the output of the LCD display in Proteus simulation. The results was shown in Table 5.2 as well as a graph in Figure 5.7 which shows that there is a linear increase in the output current versus the

input current. Therefore, the voltage sensing circuit is accurate and it gives a 1.33% error.

### Output Current (A)

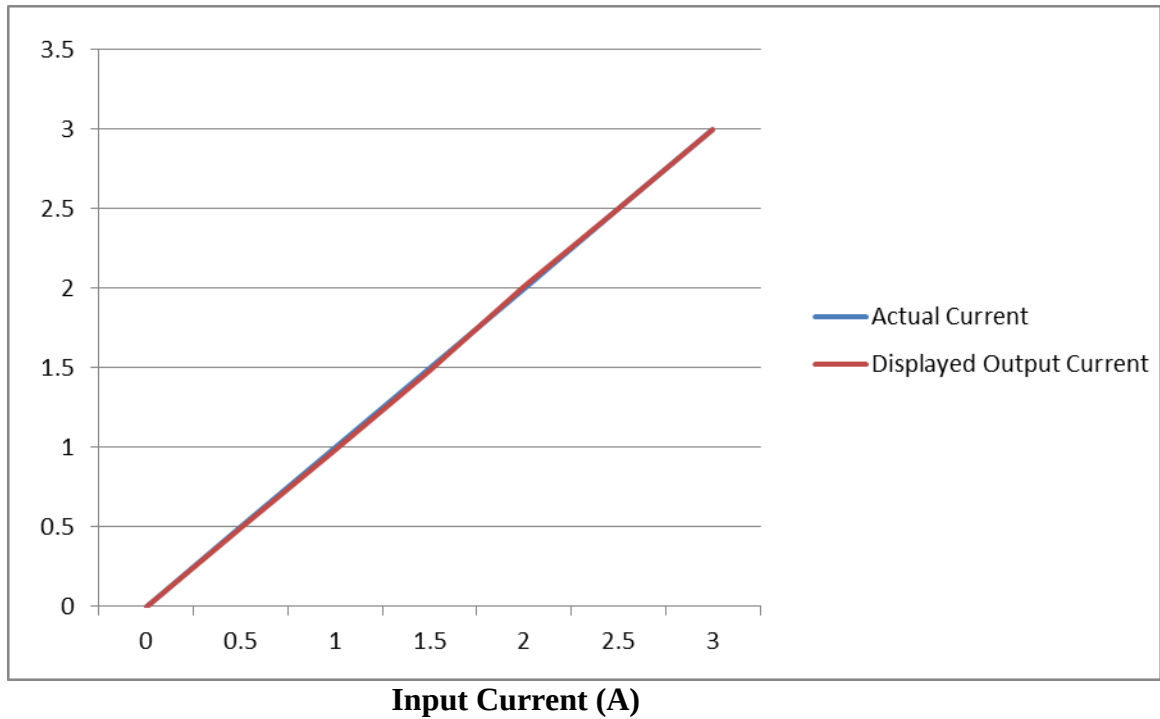


**Figure 5.8** Output current versus input current for actual and displayed current

The power readings obtained from the power meter is acceptable as it is close to the actual result and the error obtained while taking the measurement also solely depends on the error of both the current and the voltage reading.

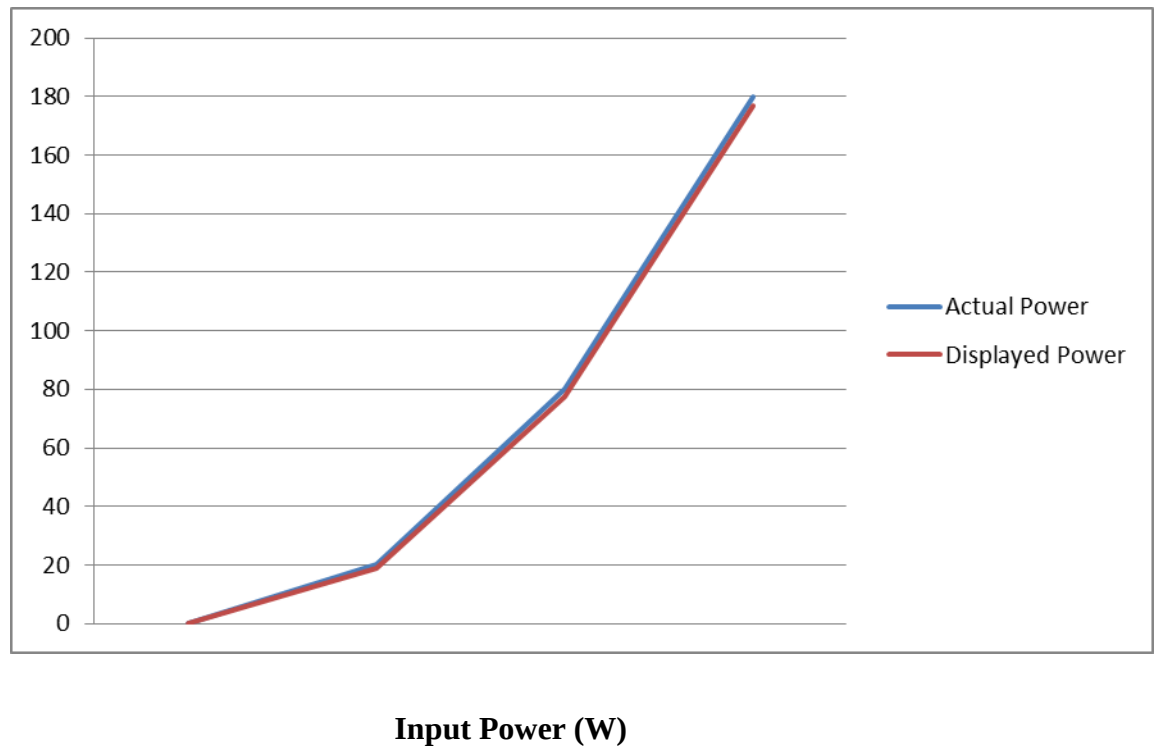
**Output Power (W)**

**Figure 5.9** Input Power Versus Output Power

The power factor measurement is done by dividing the value of Power and Apparent Power as obtained in the measurement. This could be tested with the overall circuit by obtaining reading from LCD display. The error from the Power Factor depends solely from the error of current and voltage.

The overall results obtained both simulation and hardware is acceptable and satisfactory as discussed above. The final prototype was build by a printed circuit board and a strip board. Furthermore it also achieved its purpose of being simple and user friendly as the design have only one button

## **CHAPTER 6**

### **CONCLUSION AND RECOMMENDATIONS**

#### **6.1 Conclusion**

Finally a power meter was developed. Hereby, it can measure voltage, current, power and power factor. Thereby, achieving all the objectives within the scope of the project. This design also is cheap and user friendly as was initially intended. Hence, it has potential to be commercialized after necessary modification and improvements.

## **6.2 Recommendations**

There are a few measures have to be taken in order to improve this product. Firstly, is by making some necessity amendments in the programming so that this device can be able to measure non-sinusoidal current waveform.

Next, the microcontroller used can be upgraded than used in this project which is ATMEGA 8 ,by doing so one can obtain more flash memory and more complex features in programming can be added to improve this device.

Finally, extra features can be added to improve the commercial value of the device such as enabling the device to measure cost as well as energy. In ordinance, this would definitely increase the users awareness of the level of energy consumed

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- [6] "Brand Electronics Digital Power Meter".<http://www.energytools.com/pwrmeter.htm>
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- [8] Mohd Ashphan bin Mohd Nor (2003) "Development of Digital Energy Meter for Domestic Appliances". Universiti Teknologi Malaysia : Bachelor of Electrical Engineering Thesis

## APPENDIX A

### AVR ATMEGA8 Program

```
#include <avr/io.h>
#include <avr/interrupt.h>

#include "display.h"
#include "measurement.h"
#include "adc.h"
#include "shutdown.h"
#include "eeprom.h"
#include "timer.h"
#include "buttons.h"

static unsigned char timer_cnt = 0;

/* int flags */
static unsigned char timer_irq = 0;
static unsigned char ext_irq = 0;

void toggle_display(void) {
    static unsigned char current = DISPLAY_MODE_UIP;
    if(current == DISPLAY_MODE_UIP)
        current = DISPLAY_MODE_E_POWERON;
    else if(current == DISPLAY_MODE_E_POWERON)
        current = DISPLAY_MODE_E_OVERALL;
    else if(current == DISPLAY_MODE_E_OVERALL)
        current = DISPLAY_MODE_UIP;
```

```
        display_set_mode(current);
    }

int main(void) {

    /* initialize the display */
    display_init();

    /* initialize the eeprom */
    eeprom_init();

    /* initialize the measurements */
    measurement_init();

    /* initialize the adc */
    adc_init();

    /* initialize the shutdown-controller */
    shutdown_init();

    /* initialize the timer */
    timer_init();

    /* initialize the buttons */
    buttons_init();

    /* show voltage, current, power */
    display_set_mode(DISPLAY_MODE_UIP);

    for(;;) {
```

```

        if(timer_irq) {
            timer_irq = 0;

            if(shutdown_get_state() ==
SHUTDOWN_STATE_RUNNING) {

                timer_cnt++;

                /* ~ 5 updates/sec */
                if(timer_cnt % 3 == 0) {
                    adc_sample();
                    display_refresh();
                }

                /* generate ~1 sec intervals */
                if(timer_cnt == 15) {
                    /*
                     * To determine the exact interval in
seconds:
                     * perl -e 'print
(((256*PRESCALER)/F_CPU)*TIMER_CNT)'
                     * perl -e 'print (((256*256)/1E6)*15)'
                     */
                    measurement_tick(983);
                    timer_cnt = 0;
                }
            }
        }

        if(ext_irq) {

```

```

        ext_irq = 0;
        if(shutdown_get_state() ==
SHUTDOWN_STATE_RUNNING)
            toggle_display();
        else {
            shutdown_reenable();
            display_set_mode(DISPLAY_MODE_UIP);
        }
    }

    }

    return 0;
}

/* external interrupt 0 */
ISR(INT0_vect) {
    ext_irq = 1;
}

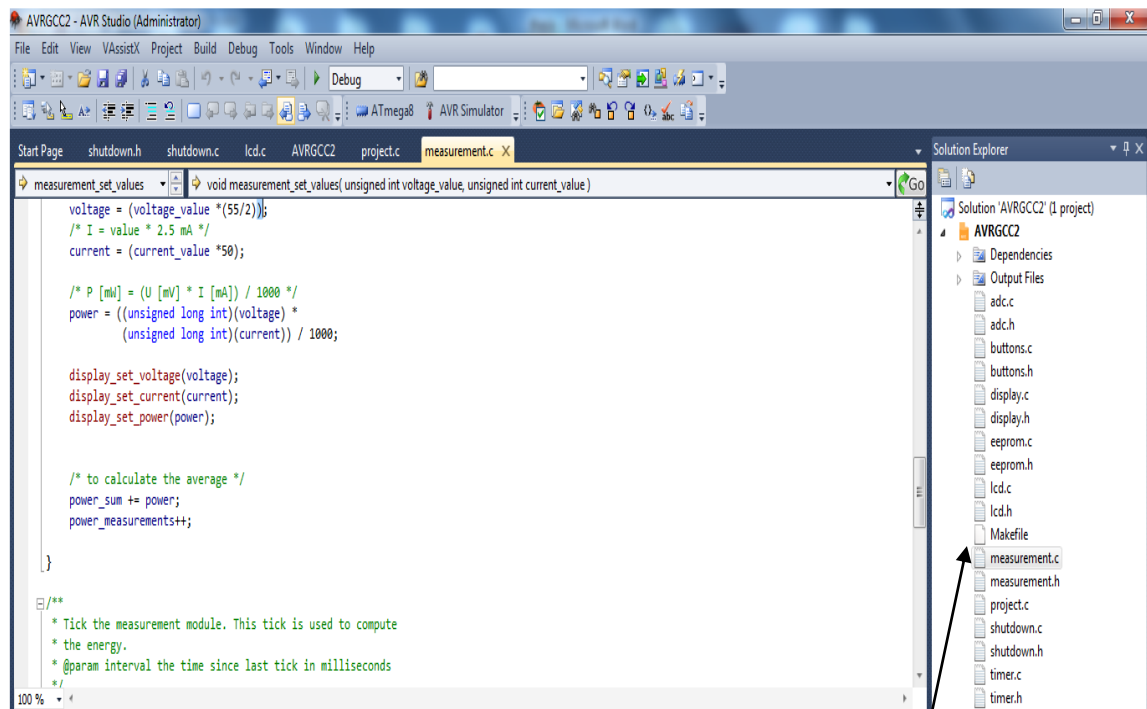
/* timer 0 interrupt */
// TODO: leave here or move somehow to timer.c?
ISR(TIMER0_OVF_vect) {
    timer_irq = 1;
}

```

## APPENDIX B

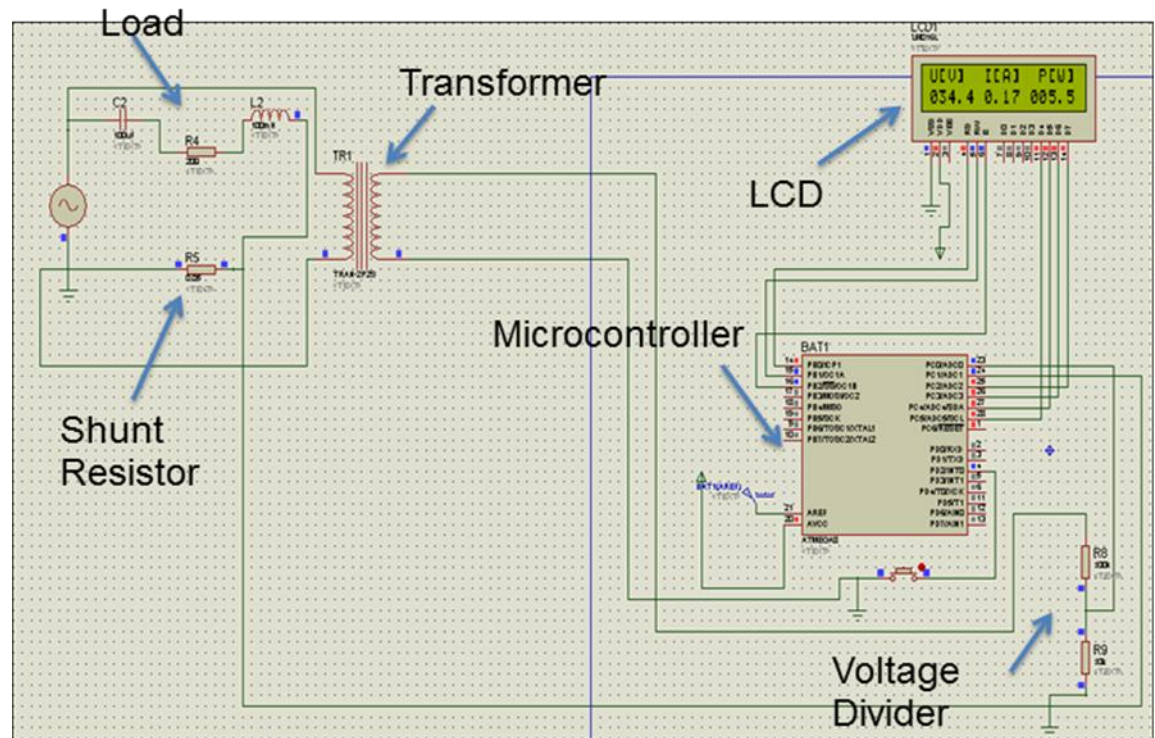
### User Manual For Power Meter

1. Open the AVR Studio 5
2. Open the filename powermeter.sln
3. A Window will open as below



All the C++ files in  
the program

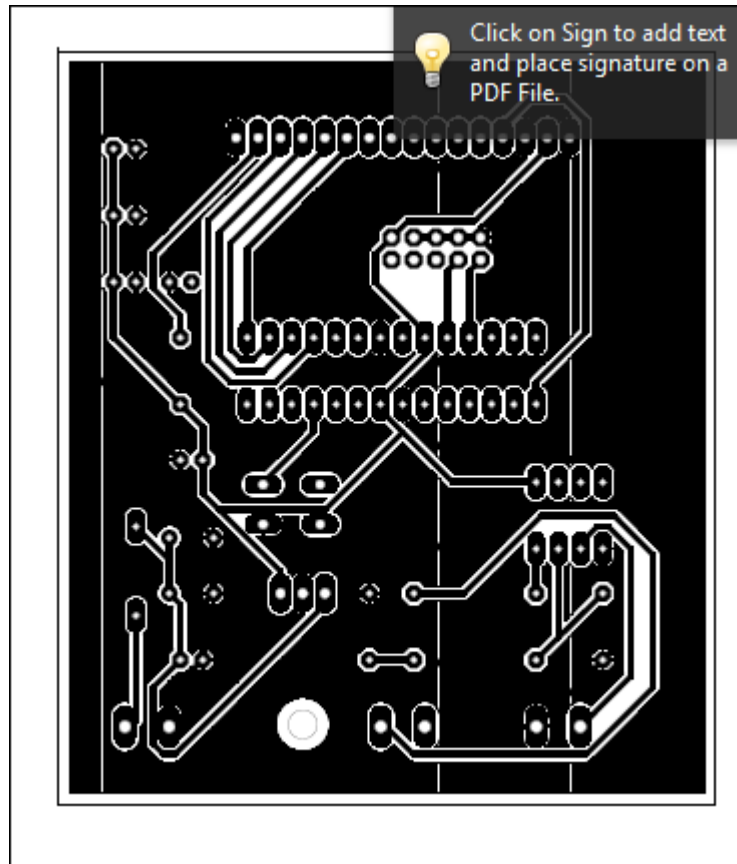
4. Click on the “Build” tab and click “Build Solution”
5. The object file and .hex file will be generated in MY DOCUMENT
6. Open PROTEUS Application and build the circuit as below:-



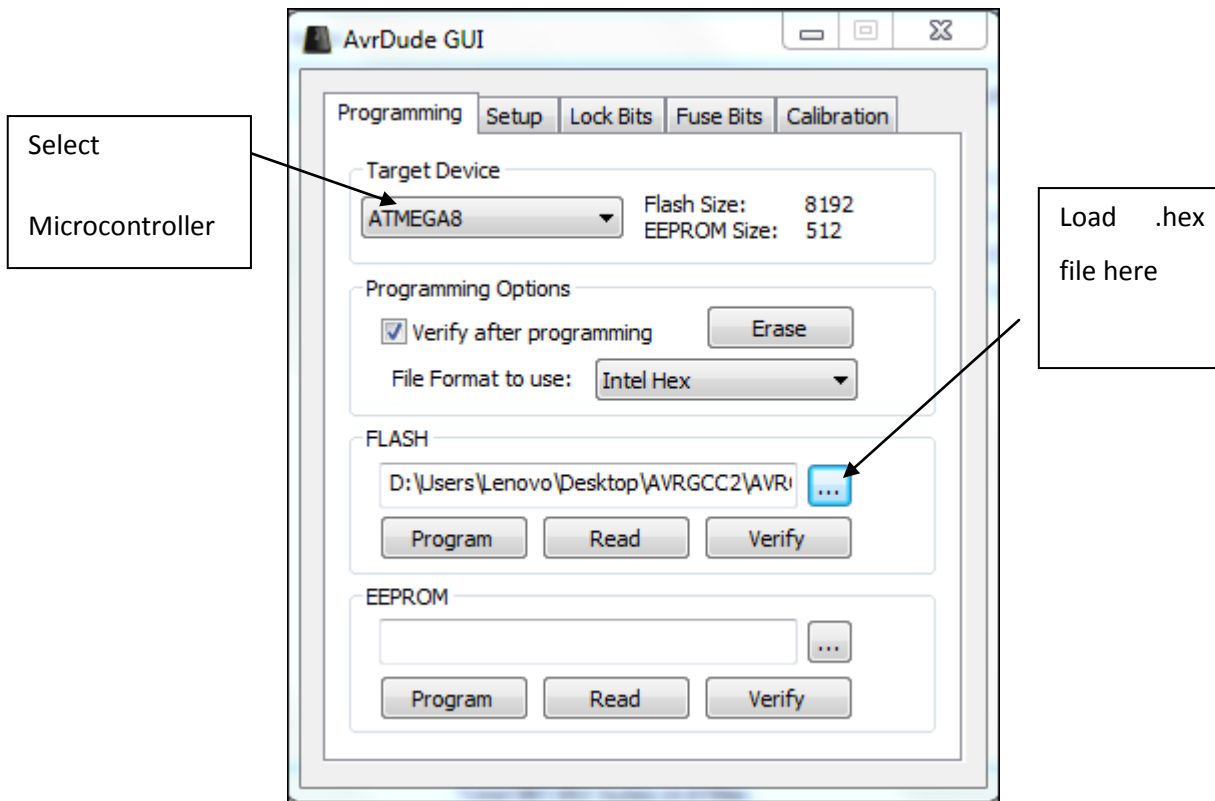
7. Next load the .hex file in PROTEUS as shown in the User Manual for Proteus.  
(APPENDIX D)

#### Hardware Design (PCB)

1. Open the file Schematic.brd in EAGLES as shown in Figure 4.7
2. Click FILE then click "Switch to Board"
3. The Layout File will open and SAVE as Image file or .pdf and the PCB board is ready for fabrication as shown below.



4. Next build the circuit and use the AVR DUDE GUI to transfer the .hex file into the board using the USBtiny Programmer or other compatible programmer.



5. Select Microcontroller and load the .hex file as shown above.
6. Select the setup tab and choose COM PORT
7. Finally click the Program Button as above.





## **Appendix C**

User Manual for AVR Studio 5

## **Appendix D**

### **User Manual for Proteus**

Proteus is software that is required to be bought. This trial version of this software may be downloaded on [www.download.cnet.com](http://www.download.cnet.com). This will be a version that has limitations on the time that it can be used as well as the functions that can be done by the software. Once the trial or full version has been obtained, the software can then be installed by just running the .exe file and follow the installation process till the end. This software is easy to use. Once installed, there will be two programs, ARES and ISIS. For the microcontroller design, ISIS is used. The first step is to open the program. To begin the design, simply click on the pick component from library button and choose the required component and place it in the workplace (figure Appendix D1). Once the design is done, double click on the microcontroller to set the program file into the microcontroller (figure Appendix D2). Logic analyzing can be done by attaching probes to the wires, opening the logic analyzer and running the program. The data will be displayed as a timing diagram. (Appendix D3).



